## GENERAL RESULTS OF THE METEOROLOGICAL CRUISES OF THE "OTARIA" ON THE ATLANTIC IN 1905, 1906, AND 1907.

WE have already reported preliminary results of the expedition which we organised in 1905 for the study of the trade-wind and the anti-trade by means of free balloons the trajectories of which were determined by triangulation (NATURE, vol. lxxiii., pp. 54–6, 449–50).

Since then two expeditions have been sent out on the Atlantic during the summers of 1906 and 1907, and Fig. 1 shows the regions which have been studied. As may be seen by the dates entered on the route of the *Otaria* (Fig. 1), many of the important points were visited in different years and at different times during the same year. This gives a much greater value to our conclusions, because the accidental phenomena are thereby, to a certain extent, eliminated.

In consequence of the investigations made by Prof. Hergesell on board the Prince of Monaco's yacht *Princesse Alice,* in the region between the Canaries and the Azores, this distinguished meteorologist was impressed by the existence of the north-west winds which he observed at a variable height above the surface winds, represented generally by the north-east trade. These north-west winds, which had not been observed before because the methods of aërial soundings have only been employed for a few years, do not themselves present marked peculiarities, since, as Dr. Hann has remarked, if one turns to the chart of isobars at different heights, which was published by M. Teisserenc de Bort twenty years ago, it is seen that at about 4000 metres there exists a barometric gradient extending from the Gulf of Mexico towards the north-east, a gradient which should in most cases, at these heights, produce currents from the west or north-west. In his communication to the Meteorological Conference at St. Petersburg, Prof. Hergesell questioned the existence of the ordinary south-west anti-trade, believing that these north-west winds were themselves a much deflected return branch of the equatorial current.

As we endeavoured to demonstrate by our first expedition of 1906, the anti-trade exists generally above the trade, and, as will be seen by the following results of the two later expeditions, the existence of the north-west winds is not incompatible with the presence of the anti-trade, and this fact should be emphasised. Of course, since the meteorological phenomena do not follow the regular zones that theory requires, but group themselves around barometric maxima having more or less ellipsoidal contours, it cannot be expected that the normal superposition of winds above the same place will be encountered every day. There are days, for example, when the north-east winds, ordinarily confined to a few hundred metres, extend up to five or six kilometres, or even more; in other cases a north-west current, superposed on the trade, encroaches more and more on the high atmosphere up to such a height that the balloons do not show any anti-trade. But the normal condition is easily deduced from the documents gathered by our three expeditions, and it occurs so frequently that each expe-

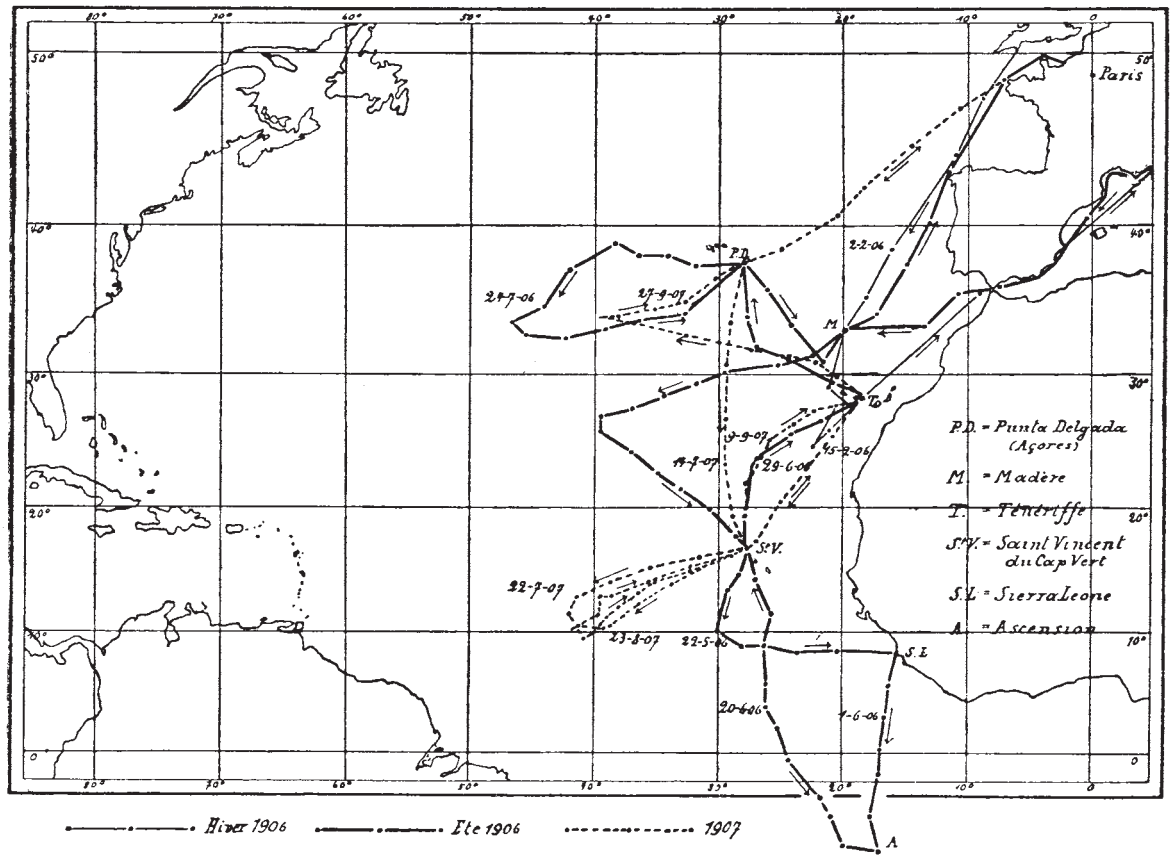


FIG. 1.—Map of the Cruise of the *Otaria.*

dition, considered individually, leads to the same conclusion. In general, the zone where the anti-trade is most regular appears to be situated to the eastward of the meridian passing through the centre of greatest pressure. To the southward of the maximum, and when it is very pronounced, northerly winds are frequent up to so great a height as eleven kilometres, which was the limit of observation here.

From the beginning of the year 1906 we were able to show by ascensions of pilot balloons, made over the open ocean to the south-west of the Canaries, that the winds with a southerly component, which we had already observed in 1905, also occurred far away from land, and even appeared to be more marked than near the islands.

During the months of May, June, July and August, 1906, the *Otaria* made another cruise which extended to Ascension Island (latitude 7° 55′ S.), and on this expedition a number of *ballons-sondes* were launched. These results, combined with those from kites flown at the same time, enabled the types of vertical temperature distribution to be determined for the regions traversed.

The lower stratum, having a drift from north-east, shows a rapid decrease of temperature (0°·9 to 1°·8 C. per 100 metres) in the first 500 or 600 metres, and an especially rapid decrease north of latitude 25°. Usually, above the zone of rapid decrease there is an inversion of temperature in which the wind velocity diminishes. Above the trade there is generally a north-west current (Fig. 3); then higher up, at about 2500 metres, near the Tropic of Cancer, and at 3000 or 3500 metres north of the tropic, there occurs a wind with a southerly component, except in the cases already mentioned. The direction of these winds possessing a southerly component, however, changes with the latitude, as might be expected from the effect of terrestrial rotation. They are south-east near 15° N. and west-south-west near 25° N., no doubt gradually changing from one to the other of these directions after passing by the south.

These same characteristics are found in the south-east trade, above which there are in general calm strata, sometimes of great thickness, then winds with a northerly component mixed with interlaced currents from the south-west, corresponding to the north-west winds of the northern hemisphere (Fig. 3). This region, however, has only been studied to about latitude 8° S.

At the limit of the two trades the winds are easterly at all heights, up to at least 14 kilometres, with a component which is sometimes north and sometimes south, but in general very weak, depending upon the exact spot where the rise of air takes place. North of the Tropic of Cancer the distribution of the winds becomes much more irregular, and it frequently happens that there is no anti-trade (Fig. 4). However, the regular *régime* of the trades appears to persist to about latitude 35° N. for places situated to the east of longitude 37° W. Farther west, winds from

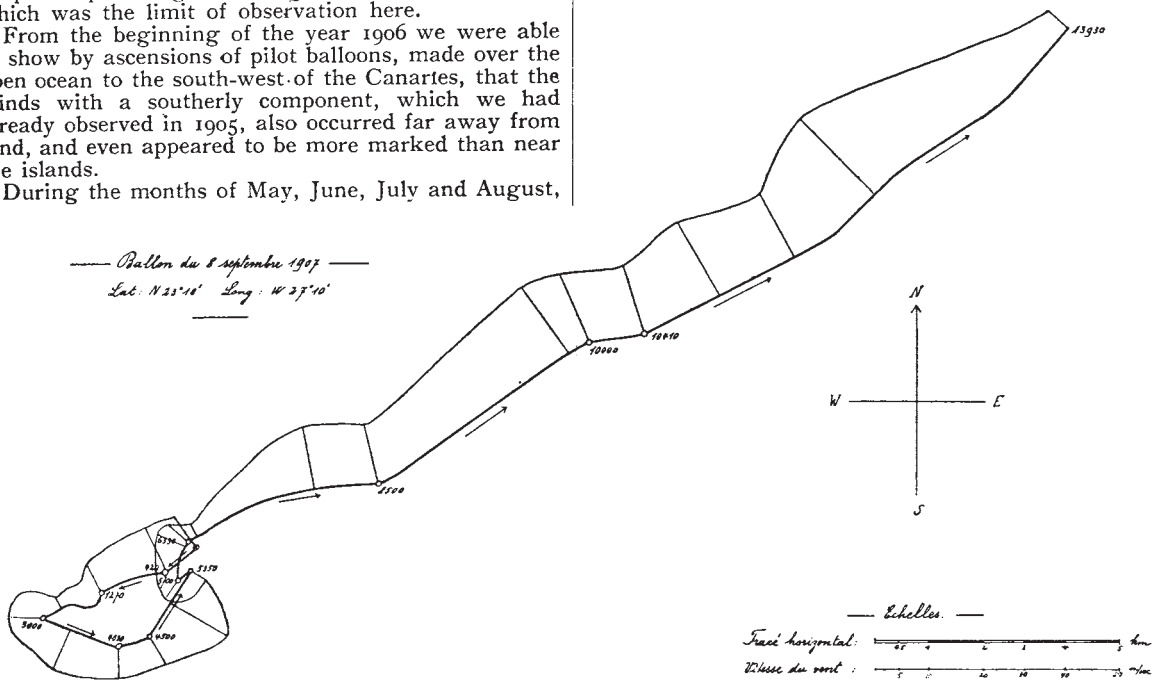


FIG. 2.—Motion of air in the region of the trade winds, showing a layer of N.W. wind and anti-trades.

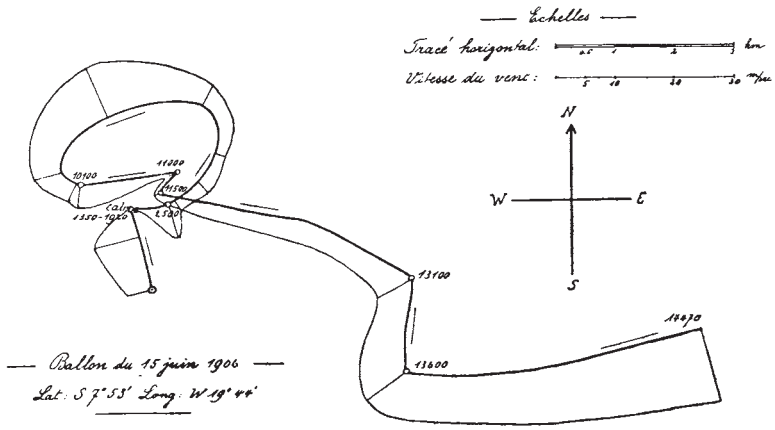


FIG. 3.—Motion of air at 7° south, showing S.E. trade winds and general eastward motion in upper atmosphere.

south to south-west prevail, which are explained by the distribution of the isobars.

Another campaign from July to October, 1907, gave the same general results, as well for the direction of the atmospheric currents as for the vertical distribution of temperature (Figs. 2 and 4). This voyage was not continued further south than 10° N., but the vessel remained twice during twelve days near this parallel, this latitude having been selected on account of the regularity of the trade wind. Again the easterly

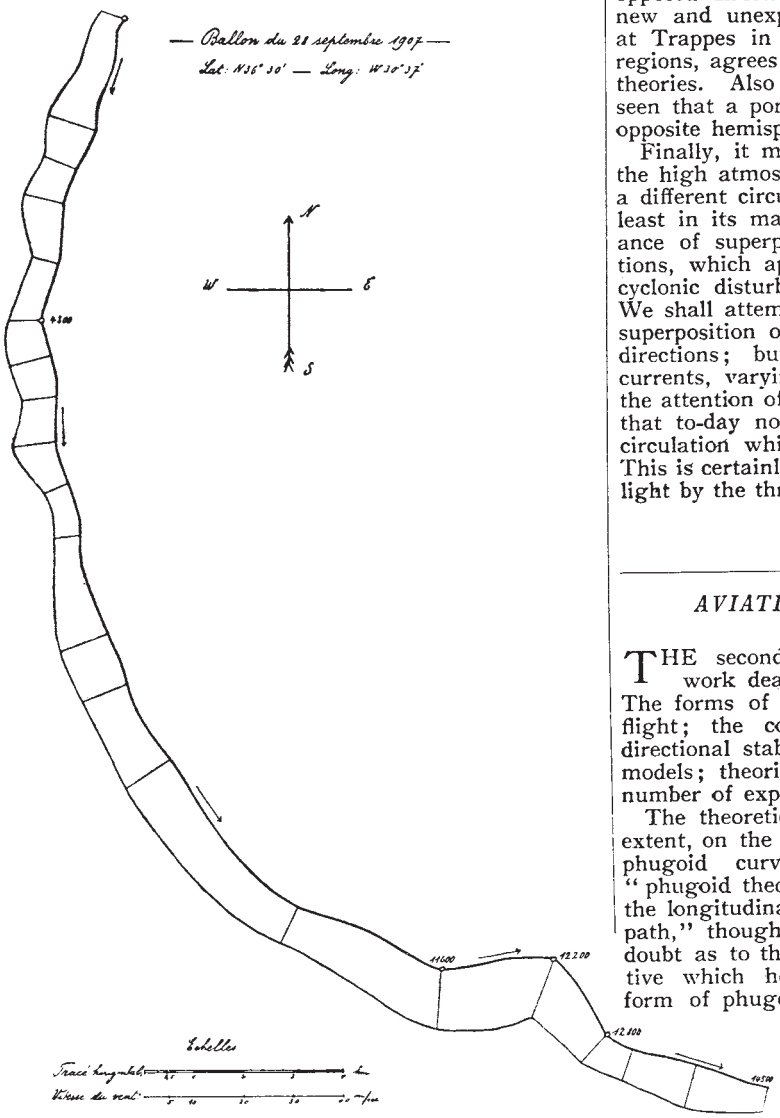


FIG. 4.—Motion of air in the atmosphere in the region of the Azores.

*Note.*—In all the figures the numbers give the altitude and the breadth of the lines the velocity of the wind.

current predominated at all heights, and also the layer of inverted temperature near 1000 metres.

The *ballon-sonde* ascensions made in 1907 were somewhat higher than before, and the isothermal layer was reached at 14 kilometres in latitude 25° 18′ N. North of 25° the isothermal layer was often met with at altitudes varying from 12 to 14 kilometres, while to the south of this parallel it was not reached, although the balloons many times exceeded 15 kilometres. Therefore, it appears that the altitude at which the temperature ceases to decrease is much greater near the equator than in moderate latitudes. This distribution of temperature is also confirmed for the regions of the Azores and Canaries, as far as about 25° N., by the ascensions of *ballons-sondes* made by Prof. Hergesell.

Our conclusions concerning the direction of the upper currents correspond in substance with former ideas about the anti-trades, apart from the situations which produce currents of very different and almost opposed directions lying one above the other. This new and unexpected fact, which was also observed at Trappes in the barometric maxima of our own regions, agrees tolerably well with certain of Maury's theories. Also near the equator it can be distinctly seen that a portion of the anti-trade comes from the opposite hemisphere.

Finally, it may be said that, if the exploration of the high atmosphere over the Atlantic does not show a different circulation from that already supposed, at least in its main features, it emphasises the importance of superposed strata flowing in various directions, which appear to persist in the regions where cyclonic disturbances of large diameter rarely form. We shall attempt later to give an explanation of the superposition of two or three strata having different directions; but the stratification of numerous thin currents, varying in their motions, is a fact worthy the attention of meteorologists, for we must recognise that to-day no theory explains this special mode of circulation which extends over a very large region. This is certainly one of the important facts brought to light by the three cruises of the *Otaria*.

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## *AVIATION, MATHEMATICAL AND OTHERWISE.*[1]

THE second volume of Mr. Lanchester's large work deals mainly with the following points:—The forms of the paths described by bodies in free flight; the conditions of longitudinal, lateral, and directional stability; the theory and use of scale-models; theories of soaring flight; and a large number of experimental verifications.

The theoretical discussions are based, to a large extent, on the consideration of what the author calls phugoid curves. According to the "Glossary, "phugoid theory" means "the theory dealing with the longitudinal stability and the form of the flight path," though in a footnote the author raises some doubt as to the appropriateness of the Greek derivative which he has himself coined. The simplest form of phugoid curve, to the study of which the author devotes considerable attention, might form the subject of problems that would delight the heart of the old-fashioned tripos examiner. Like the latter's particle on his perfectly smooth surface, the gliding body is supposed to have its mass concentrated at a single point and to travel without loss of energy, and the supporting surface is supposed to be small and to be always tangential to the direction of motion. In other words, the problem reduces to that of a particle acted on by gravity and by a supporting force (due to the air) which is always normal to the

[1] (1) "Aërodonetics." Constituting the Second Volume of a complete Work on Aërial Flight. By F. W. Lanchester. Pp. xvi+433. (London: A. Constable and Co., Ltd, 1908.) Price 1*l.* 1*s.* net.
(2) "Artificial and Natural Flight." By Sir Hiram S. Maxim. Pp. xv+166. (London: Whittaker and Co., 1908.) Price 5*s.* net.